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Nutritional Levels of Diets Fed to Captive Amazon Parrots: Does Mixing Seed, Produce, and Pellets Provide a Healthy Diet?

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Abstract: Poor nutrition is a serious problem in captive psittacine birds. Seed-based diets are known to contain excess fat, low calcium : phosphorus ratios, and other nutrient deficiencies, whereas many consider nutritionally superior, formulated diets to be monotonous. As a result, many bird owners feed a mixture of seed, produce, and formulated diet. However, the nutritional contents of such mixed diets have rarely been evaluated. In this study, we describe the nutrient contents of diets consumed by 7 adult (>6 years old), captive Amazon parrots offered produce (50% fresh weight), formulated diet (25%), and seed (25%). Diets consumed were deficient in calcium, sodium, and iron and contained more than the recommended amount of fat. In addition, the birds chose foods that exacerbated these imbalances. Birds offered low-seed diets (60% pellet, 22% produce, 18% seed, wet weight) consumed diets with more fat than recommended but acceptable levels of calcium and all other nutrients measured, as well as acceptable calcium : phosphorus ratios. This suggests that small quantities of seeds may not result in nutritionally imbalanced diets. Birds fed 75% formulated diet and 25% produce consumed diets within the recommendations for nearly all measured nutrients, demonstrating that owners of psittacine birds should be encouraged to supplement manufactured diets with low energy-density, fresh produce items to provide stimulation and foraging opportunities without fear of causing major nutritional imbalances.

Key words: nutrition, seed, formulated diet, produce, avian, Amazon parrot, *Amazona* species

Introduction

Inadequate nutrition and the diseases it causes remain serious problems in avian medicine.[1,2] The poor nutritional state of psittacine birds presenting to veterinary clinics is likely the result of several factors: a general lack of research on the nutritional requirements of captive parrots; insufficient knowledge, on the parts of both owners and veterinarians, of psittacine nutrition; a reluctance by owners to convert their birds to nutritionally superior diets; and the nutritional imbalances of many "mixed" diets.[3–6] Most recommendations for psittacine nutrition can be traced back to studies of domestic poultry supplemented by work on captive budgerigars (*Melopsittacus undulatus*) and cockatiels (*Nymphicus hollandicus*).[7–9] However, poultry and parrots are not closely related and differ both developmentally and ecologically. As a result, current diet recommendations are likely suboptimal for many captive parrots.

It is not just a lack of basic nutritional knowledge that is at the root of the psittacine nutritional-health problems. Many owners are apparently unaware of the basic principles of avian nutrition and continue to feed their large parrots seed-based diets.[4,10] This problem is exacerbated by the marketing of seed-based diets by bird food manufacturers claiming that such diets are complete, balanced, and healthy.[11,12] Relative to the nutritional needs of psittacine birds, seed-based diets contain excess fat, low calcium : phosphorus (Ca : P) ratios, and insufficient levels of calcium, phosphorus, sodium, zinc, iron, lysine, and vitamin A.[3,10,13] Nutritionally superior, formulated diets are widely available from many manufacturers. This suggests that educating

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bird owners and veterinarians should increase the number of captive parrots fed nutritionally adequate diets. However, many knowledgeable pet owners are hesitant to feed formulated diets because they fear their birds are unwilling to change their eating habits. Others are hesitant because formulated diets provide little stimulation and few foraging opportunities, and foraging is considered an important part of captive parrot enrichment.[14] Some diet manufacturers, apparently aware of these concerns, provide guidelines for supplementing formulated diets with other foods. However, these recommendations vary among manufacturers and are presented without an explanation as to how supplementation affects the nutritional content of diets consumed.[15–22] Because of these conflicting pressures, many bird owners feed mixed diets containing varying percentages of seeds, nuts, fresh produce, and formulated diets.[4] Determining the nutritional levels of these mixed diets is complicated by the selective consumption of preferred ingredients by parrots. Although some research in this area has been conducted, more information is needed to properly evaluate these popular diets.[3,5]

The objectives of this study were 1) to analyze the nutritional content of a mixed diet composed of seed, fruits, vegetables, and a commercially available, formulated diet offered to, and consumed by, a group of captive Amazon parrots; 2) to report the changes in nutrient concentrations of diets consumed as the birds were transitioned to a diet of 100% formulated product; and 3) to compare the nutritional content of the consumed diets with published, nutritional recommendations to determine which diets may be most appropriate for large, captive psittacine birds.

Materials and Methods

Birds and housing

The study was conducted from February 12, 2007, to June 7, 2007, at the Schubot Exotic Bird Health Center (Texas A&M University, College Station, TX, USA). Seven Amazon parrots of unknown ages were included in the study: 3 yellow-shouldered (*Amazona barbadensis*), 2 yellow-crowned (*Amazona ochrocephala*), 1 blue-fronted (*Amazona aestiva*), and 1 lilac-crowned (*Amazona finschi*) parrots. Each of the birds in the study was brought as an adult to Texas A&M University before 2001 because of a history of exposure to avian herpesvirus. During the study, some of the birds presented cloacal or choanal papillomas but were otherwise considered healthy. All birds ate well throughout the study.

The birds were housed in the Schubot Exotic Bird Health Center Aviary, a roofed building with a concrete floor, one solid wall, and 3 walls of thick, wire mesh. All birds were housed singly in suspended, wire-mesh cages, which allowed discarded food to fall through the cage floor. During the study, wire-mesh trays lined with clear plastic were hung underneath the cages to catch pieces of falling food.

Feeding and diet conversion

All 7 birds had been receiving approximately the same diet for the 5 years preceding the study, which consisted of approximately 28% seed/nut/grain mix (Vita Parrot Formula, Vitakraft Sunseed, Bowling Green, OH, USA), 49% mixed raw produce by wet weight, and 23% formulated diet (Avian Maintenance FruitBlend Flavor Diet, ZuPreem, Shawnee, KS, USA). This was referred to as the seed/produce/pellet diet (Table 1). The produce mix included 3-mm to 5-mm slices of carrot and celery, 15-mm apple cubes, whole corn kernels, and whole grapes. None of the produce was peeled. In addition, 1 peanut was given to the birds on 60% of the days (~2% of the total diet by fresh weight). Throughout the study, food and water were provided once daily between midmorning and midafternoon.

The birds were fed this baseline diet for 7 days before the diet conversion began. During this time, each food type offered and not consumed after 24 hours was weighed. For the diet conversion study, 3 birds were randomly assigned to continue receiving the seed/produce/pellet diet (control birds), whereas 4 birds were converted, in 3 phases, from the baseline diet to a diet of 100% formulated diet (treatment birds). During the first phase of diet conversion, the treatment birds were offered ~60% formulated diet, 22% produce, and 18% seed mix, which was referred to as the pellet/produce/seed diet (Table 1). After 12 days on this diet, the amount of food offered and consumed during 1 day was measured. Throughout the next phase of the study, the treatment birds were offered ~75% formulated diet and 25% produce, which was referred to as the pellet/produce diet (Table 1). Twelve days after that phase began, the amount of food offered and consumed during 1 day was measured. In the final phase, the birds were offered 100% formulated diet, or a pellet-only diet. After 25 days on that diet, the amount of food offered and consumed was measured for 4 days. To document changes in body weight, each bird was

Table 1. Composition of diets offered to 4 species of captive Amazon parrots (N = 7 birds total). Relative quantities of each dietary component (mean ± SD) are given in percentage of fresh weight and the total weight of each diet is given in grams.

Diet components	Seed/produce/pellet diet, %	Pellet/produce/seed diet, %	Pellet/produce diet, %	Pellet diet (%)
Formulated pellets	23 ± 4	60 ± 1	75 ± 3	100
Produce	49 ± 5	22 ± 1	25 ± 3	
Apples	11 ± 3	3 ± 0.4	4 ± 1.1	
Grapes	6 ± 1.2	5 ± 0.6	11 ± 2	
Celery	14 ± 2	6 ± 0.5	4 ± 1.5	
Carrots	14 ± 2	7 ± 0.5	6 ± 2.6	
Corn	3 ± 0.5	2 ± 0.5	6 ± 0.7	
Seed mix, nuts, grains	28 ± 3	18 ± 0.5		
Safflower seeds	7 ± 0.7	5 ± 0.5		
Sunflower seeds	6 ± 1.8	4 ± 1.2		
Buckwheat	6 ± 0.5	4 ± 0.4		
Oats	3 ± 0.5	2 ± 0.3		
Oat groats	2 ± 0.8	2 ± 0.5		
Peanuts	2 ± 1.8	1 ± 0.4		
Squash seeds	1 ± 0.6	1 ± 0.4		
Other seeds	0.4 ± 0.2	0.3 ± 0.2		
Refuse	0.3 ± 0.2	0.2 ± 0.1		
Total diet offered, g	81 ± 3	61 ± 1	75 ± 6	58 ± 3

weighed within 30 days of the start and 14 days of the end of the study.

Dietary analyses

To quantify the amount of each food item consumed, each item was weighed to the nearest 0.01 g before being offered to the birds. After approximately 24 hours, uneaten items were reweighed. Correction for weight change during the 24 hours, consisting primarily of water loss from produce and water gain by formulated diet, was determined by placing a bowl of food out for each diet type and reweighing each constituent part 24 hours later (according to Carciofi et al[23]). The nutrient content of the daily diet consumed by each bird was estimated by subtracting the weight of each item recovered from the amount offered, correcting the resulting value for water gain or loss, and multiplying the amount consumed by the nutritional content for each item, as reported in the US Department of Agriculture National Nutrient Database for Standard Reference.[24]

Nutritional values for the formulated diet were obtained from standard laboratory analyses of dried samples, performed at Eurofins Scientific Inc (Des Moines, IA, USA), for amino acid profile and levels of β-carotene, total vitamin A, and total vitamin E, and at the Palmer Research Center, University of Alaska (Palmer, AK, USA), for predicted metabolizable energy and levels of crude protein, crude fat, phosphorus, potassium, calcium, magnesium, sodium, copper, zinc, manganese, and iron. Concentrations of proline, aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, total lysine, histidine, and arginine were determined via acid hydrolysis in 6 N HCl at 110°C for 24 hours and quantified via ion-exchange chromatography with a postcolumn ninhydrin reaction and ultraviolet/visible detection (AOAC method 982.30).[25] Cystine and methionine concentrations were determined by using performic oxidation for conversion to cysteic acid and methionine sulfone, respectively. The sample was then hydrolyzed to release cysteic acid and methionine sulfone. Quantification was performed by using ion-exchange chromatography with an *o*-phthalaldehyde postcolumn reaction via the AOAC method 994.12.[26] The concentration of tryptophan was determined by alkaline digestion with lithium hydroxide at 110°C for 22 hours and quantified via reverse-phase chromatography with ultraviolet/visible detection (AOAC methods 988.15, 982.30, and 994.12[25,27,28]). β-Carotene and total vitamin A concentrations were determined by extraction with hexane, separation on a silica column, and quantification with a fluorometric detector.[29,30] For determination of total vitamin E concentrations, the sample was saponified and extracted into ether by liquid phase extraction. The extract was filtered and separated on a silica column with fluorescence detection (AOAC 971.30).[31] The crude protein concentration was calculated using the Dumas method in a LECO CHN-1000 analyzer for carbon, hydrogen, and nitrogen; and the crude fat concentration was calculated by using the ether extraction method.[32] Predicted metabolizable energy was calculated by using the formula[33,34]:

$$\textit{Predicted metabolizable energy}\ (\mathrm{kJ/100\ g\ dry\ matter}) = (18.4 \times \textit{crude protein}) + (36.4 \times \textit{crude fat}) + (16.7 \times \textit{soluble carbohydrate}).$$

Concentrations of calcium, potassium, phosphorus, magnesium, iron, sodium, zinc, and copper were determined by boiling 0.25 g of each sample in 20 mL of 5:3 nitric : perchloric acid until most of the liquid was gone, then mixing with deionized water and reading the concentrations of each nutrient via inductively coupled plasma mass spectrometry.[35]

To determine the nutrient content of the seed mix, 10 samples of the mix were separated into their constituent ingredients and weighed. The nutritional content was calculated by using the nutritional value of the seed kernels and the percentage by weight of husk for each type of seed.[24] Because of the considerable time required to separate the seeds, the relative amount of each seed type consumed was calculated over 3 days for each bird, and values were averaged. The amount of whole seed recovered after feeding each day was subtracted from the amount offered to each bird, and the nutritional content was estimated by using the mean of the detailed seed analyses.

Statistical analyses

Linear regression was used to determine whether the percentage of consumption of food items varied significantly with the concentration of individual nutrients. A sign-rank test was used to determine whether the mean nutrient content of the diet offered differed from that consumed for each bird.[36] To determine whether the diet consumed by the birds on the seed/produce/pellet diet differed significantly from reported recommendations, the mean nutrient content for the 7 birds was tested against the mean nutrient content of psittacine diets[3,13] and reported dietary recommendations[9,37,38] by using a t test for nutrients, where there were $\geq$3 recommendations in the literature. In the case of only 1 or 2 available literature recommendations, the hypothesis that the nutrient values of the consumed diets differed from the single or averaged 2 recommended values was tested. All statistical analyses were conducted by using Statgraphics Centurion XVI (StatPoint Technologies, Warrenton, VA, USA). To quantify the variation among individuals, values for foods offered and consumed were averaged for each bird. These 7 mean values were then used to calculate the overall mean ± standard deviation (SD) presented in the tables.

Table 2. Fresh weight (mean ± SD) of foods offered and percentage consumed by 7 captive Amazon parrots over a 24-hour period.

Food item	Offered, g	Consumed, %
Pellet	18.8 ± 3.1	33 ± 23
Seed and peanut mix	22.6 ± 2.2	46 ± 16[a]
Seed mix	21.0 ± 2.1	46 ± 18[a]
Peanut	1.6 ± 1.4	52 ± 41[a]
Produce	39.4 ± 4.3	34 ± 10
Apples	8.9 ± 2.8	70 ± 21
Grapes	5.1 ± 1.0	83 ± 26
Celery	11.6 ± 1.7	9 ± 18
Carrots	11.5 ± 1.5	5 ± 10
Corn	2.3 ± 0.4	60 ± 32
Total food (g)	80.9 ± 2.9	36 ± 8.4[a]

[a] Percentage of edible portion consumed.

Nutrient concentration values obtained in the diet conversion experiment were not normally distributed and did not have uniform variance. As a result, the Mood's median test and associated 95% confidence intervals (CI) were used to determine which treatment groups differed significantly. The small sample sizes for the pellet/produce/seed and pellet/produce diets prevented calculation of meaningful 95% CI. Because all birds fed the pellet-only diet received the same batch of food having approximately equivalent nutrient concentrations, there was no variance in nutrient proportions and 95% CI could not be calculated. The lack of CI prevented comparisons among the pellet/produce/seed, pellet/produce, and pellet-only diets. However, the differences in nutrient contents of these 3 diets compared with the seed/produce/pellet diet were considered statistically significant if the medians of the former fell outside the 95% CI of the latter.

Results

Baseline diet

Birds were offered a diet composed of (mean ± SD) 49% ± 0.5% produce, 28% ± 0.05% seeds and nuts, and 23% ± 0.4% formulated diet by fresh weight (N = 7; Table 2). The seed mix, containing 6 main types of seeds, was composed of approximately 55% high-fat "oil" seeds (according to Roudybush[39]), 42% low-fat seeds, and 2.5%

Table 3. Fresh weight of seed mix components offered and percentage consumed by 7 captive Amazon parrots. All data reflect the mean ± SD of 10 analyzed seed mixes.

Diet components	Offered, g per 100 g of seed mix	Consumed, %
Safflower seeds	27.3 ± 2.6	84 ± 19
Sunflower seeds	23.4 ± 6.8	98 ± 2
Buckwheat	23.0 ± 2.1	10 ± 18
Oats	10.1 ± 1.8	8 ± 13
Oat groats	8.6 ± 3.1	4 ± 11
Squash seeds	4.0 ± 2.2	80 ± 31
Other seeds[a]	1.5 ± 0.9	ND
Refuse[b]	1.1 ± 0.6	ND

Abbreviation: ND indicates not determined.
[a] Includes peppers (*Capsicum* species) and hemp seeds (*Cannabis sativa*).
[b] Includes stems, empty seed husks, leaves, etc.

miscellaneous seeds and refuse by wet weight (Table 3).

The birds consumed a daily mean of 61 ± 9.5 g of food by dry weight and 620 ± 131 kJ/g body weight, which represented approximately 36% of the edible fresh-weight portion of the diet offered (N = 7 × 7 days each; Table 2). Birds consumed 46% ± 16% of the edible portions of the seeds and nuts, 34% ± 10% of the produce, and 33% ± 23% of the formulated diet by wet weight (Table 2). Percentages of specific dietary items consumed ranged from 5% of oat groats and carrots to 83% of grapes and 98% of sunflower seeds (Tables 2 and 3). The percentage of the item consumed was significantly greater for foods with relatively high concentrations of polyunsaturated fatty acids (regression, $F_{1,11} = 5.00$, $R^2 = 42\%$, $P = .047$). Foods with relatively high total lipid content and low total carbohydrate content were also consumed in higher quantities, but the trends were not statistically significant (total lipids: $F_{1,12} = 2.7$, $R^2 = 20\%$, $P = .13$; carbohydrates: $F_{1,12} = 2.4$, $R^2 = 18\%$, $P = .15$).

Consumed diets contained significantly higher levels of total lipids, polyunsaturated fatty acids, and copper and significantly lower levels of protein, amino acids, phosphorus, potassium, sodium, iron, zinc, vitamin A, and β-carotene than total diets offered to the birds (sign-rank test: N = 7, $P < .05$ for all; Table 4). For the remainder of the nutrients, the concentrations in the foods offered and consumed did not differ.

The consumed seed/produce/pellet diet in this study differed significantly from the reported recommendations for psittacine maintenance diets. On average, consumed diets had greater than

Table 4. Nutrient content by dry weight of mixed diets (seed, produce, and formulated pellets) offered to, and consumed by, 7 captive Amazon parrots. Data are presented as the mean ± SD.

Nutrient	Offered	Consumed
Energy, kJ/g	17.8 ± 0.03	18.6 ± 0.44[a]
Protein, %	16.5 ± 0.1	15.5 ± 0.3[a]
Total lipids, %	15.5 ± 0.2	20.6 ± 3.9[a]
SFA, %	2.82 ± 0.03	2.71 ± 0.32
MUFA, %	5.02 ± 0.08	4.8 ± 0.85
PUFA, %	8.39 ± 0.08	13.4 ± 2.3[a]
Ash, %	3.86 ± 0.01	3.75 ± 0.16
Carbohydrate, %	57.6 ± 0.3	54.2 ± 4.7
Fiber, total dietary, %	6.55 ± 0.05	5.9 ± 1
Ca, %	0.4 ± 0	0.34 ± 0.13
Mg, %	0.23 ± 0	0.22 ± 0.02
P, %	0.6 ± 0	0.53 ± 0.02[a]
K, %	0.83 ± 0	0.74 ± 0.02[a]
Na, %	0.1 ± 0	0.06 ± 0.02[a]
Ca:P ratio	0.66 ± 0.01	0.64 ± 0.02
Fe, ppm	87.9 ± 0.2	70.5 ± 11.3[a]
Zn, ppm	55.6 ± 0.1	49.2 ± 6.4[a]
Cu, ppm	11.1 ± 0	12.4 ± 0.7[a]
Vitamin A, IU/g	55.6 ± 1.6	11.1 ± 8.4[a]
β-Carotene, ppm	27 ± 0.8	4.8 ± 4.3[a]
Tryptophan, %	0.25 ± 0	0.22 ± 0.01[a]
Threonine, %	0.66 ± 0	0.59 ± 0.01[a]
Isoleucine, %	0.74 ± 0	0.69 ± 0.02[a]
Leucine, %	1.44 ± 0	1.27 ± 0.08[a]
Lysine, %	1.07 ± 0	0.85 ± 0.09[a]
Methionine, %	0.4 ± 0	0.36 ± 0.03[a]
Cystine, %	0.3 ± 0	0.28 ± 0.01[a]
Phenylalanine, %	0.86 ± 0	0.79 ± 0.03[a]
Tyrosine, %	0.58 ± 0	0.5 ± 0.02[a]
Valine, %	0.97 ± 0.01	0.86 ± 0.03[a]
Arginine, %	1.61 ± 0.01	1.44 ± 0.10[a]

Abbreviations: SFA indicates saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; Ca, calcium; Mg, magnesium; P, phosphorus; K, potassium; Na, sodium; Fe, iron; Zn, zinc; Cu, copper.
[a] Offered and consumed diets differed significantly (sign-rank tests: N = 7, $P < .05$).

recommended concentrations of total lipids and magnesium (*t* test: $t > 4.7$, $df = 10$, $P < .01$ for both analyses; Table 5) and a lower Ca : P ratio, as well as lower concentrations of calcium, sodium, and iron (*t* test: $t < -3.0$, $df = 8$, $P < .05$ for all analyses; Table 5).[3,9,13,37,38] The energy density of consumed diets (18.6 ± 0.44 kJ/g) was significantly greater than the one recommendation in the literature (12.6 kJ/g, *t* test: $t = 36.4$, $df = 6$, $P < .001$; Table 5).[9] The diets contained the essential amino acids, tryptophan, threonine, methionine, lysine, and arginine, in concentrations equal to, or greater than, those recommended (Table 5), and the relative proportions of lysine to tryptophan,

Table 5. Nutrient concentrations by dry weight of diets consumed by 7 captive Amazon parrots offered a mix of seed, produce, and formulated diet compared with published recommendations for large parrots. Consumed diet measurements (mean ± SD) followed by asterisks differ significantly from the mean recommendation. Recommendations columns give the lowest and highest values from the cited literature, the mean of which was used for statistical analyses. The column "N references" shows the total number of references used for calculating the mean followed by the reference citations.

		Recommendations			
Nutrient	Consumed diet	Lowest	Mean	Highest	N references
Energy, kJ/g	18.6 ± 0.44		12.6		1 [9]
Protein, %	15.5 ± 0.3	12	16	24	5 [3,9,13,37,38]
Total lipids, %	20.6 ± 3.9***	4	5	7	4 [9,13,37,38]
Ca, %	0.34 ± 0.13*	0.50	0.69	1.10	5 [3,9,13,37,38]
Mg, %	0.22 ± 0.02**	0.06	0.12	0.15	3 [3,9,38]
P, %	0.53 ± 0.02	0.40	0.54	0.80	5 [3,9,13,37,38]
K, %	0.74 ± 0.02	0.40	0.60	0.70	3 [3,9,38]
Na, %	0.06 ± 0.02***	0.15	0.18	0.20	4 [3,9,13,38]
Ca:P ratio	0.64 ± 0.02***	1.0	1.3	1.4	5 [3,9,13,37,38]
Fe, ppm	70.5 ± 11.3***	80	110	150	3 [3,9,38]
Zn, ppm	49.2 ± 6.4	45	72	120	3 [3,9,38]
Cu, ppm	12.4 ± 0.7	8	12	20	3 [3,9,38]
Vitamin A, IU/g	11.1 ± 8.4	3	5	8	3 [3,9,38]
Tryptophan, %	0.22 ± 0.01***		0.12		1 [9]
Threonine, %	0.59 ± 0.01***		0.40		1 [9]
Lysine, %	0.85 ± 0.09	0.60	0.88	1.15	2 [9,38]
Methionine, %	0.36 ± 0.03*		0.25		1 [9]
Arginine, %	1.44 ± 0.10***		0.60		1 [9]

Abbreviations: Ca indicates calcium; Mg, magnesium; P, phosphorus; K, potassium; Na, sodium; Fe, iron; Zn, zinc; Cu, copper.
$^*P < .05$.
$^{**}P < .01$.
$^{***}P < .001$.

threonine, methionine, and arginine were also similar to literature recommendations.[9]

Diet conversion experiment

The mean weight of the birds on the experimental diets did not change over the course of the study (mean change, 0.05% ± 1.1%; N = 4 birds), whereas birds maintained on the control diet increased weight by 6.1% ± 4.2% (N = 3 birds). The total dietary lipid level was significantly less for birds fed pellet/produce/seed, pellet/produce, and pellet-only diets compared with the original seed/produce/pellet diet (Mood's median test, $P < .05$; Fig 1). The dietary lipid content was 80% less for birds eating the formulated diet relative to that of birds eating the seed/produce/pellet diet. Concentrations of 3 types of fatty acids were also significantly less for birds fed pellet/produce/seed, pellet/produce, and pellet-only diets compared with the original seed/produce/pellet diet (Mood's median test, $P < .05$). The concentration of dietary saturated fatty acids dropped by 51%, monounsaturated fatty acids by 66%, and polyunsaturated fatty acids by 69% for birds converted to pellet-only diets. The carbohydrate concentration was significantly greater, whereas the total energy density was significantly lower for birds fed pellet/produce/seed, pellet/produce, and pellet-only diets, compared with the original seed/produce/pellet diet (Mood's median test, $P < .05$; Fig 1). However, the total energy density for all diets was still greater than the value of 12.6 kJ/g recommended in the literature.[9]

The percentages of protein, threonine, and arginine showed relatively little variation among diets and were all above the minimum recommended values for all diets; however, percentages were lower in the pellet/produce diet than they were in the other diets (Mood's median test, $P < .05$; Fig 2). Lysine and methionine percentages were above the minimum percentages recommended in all diets, but both were significantly lower in the original seed/produce/pellet diet (Mood's median test, $P < .05$) and higher in birds fed the pellet-only diet (Fig 2). Most of the vitamin A in the diets was in the form of β-carotene, except in

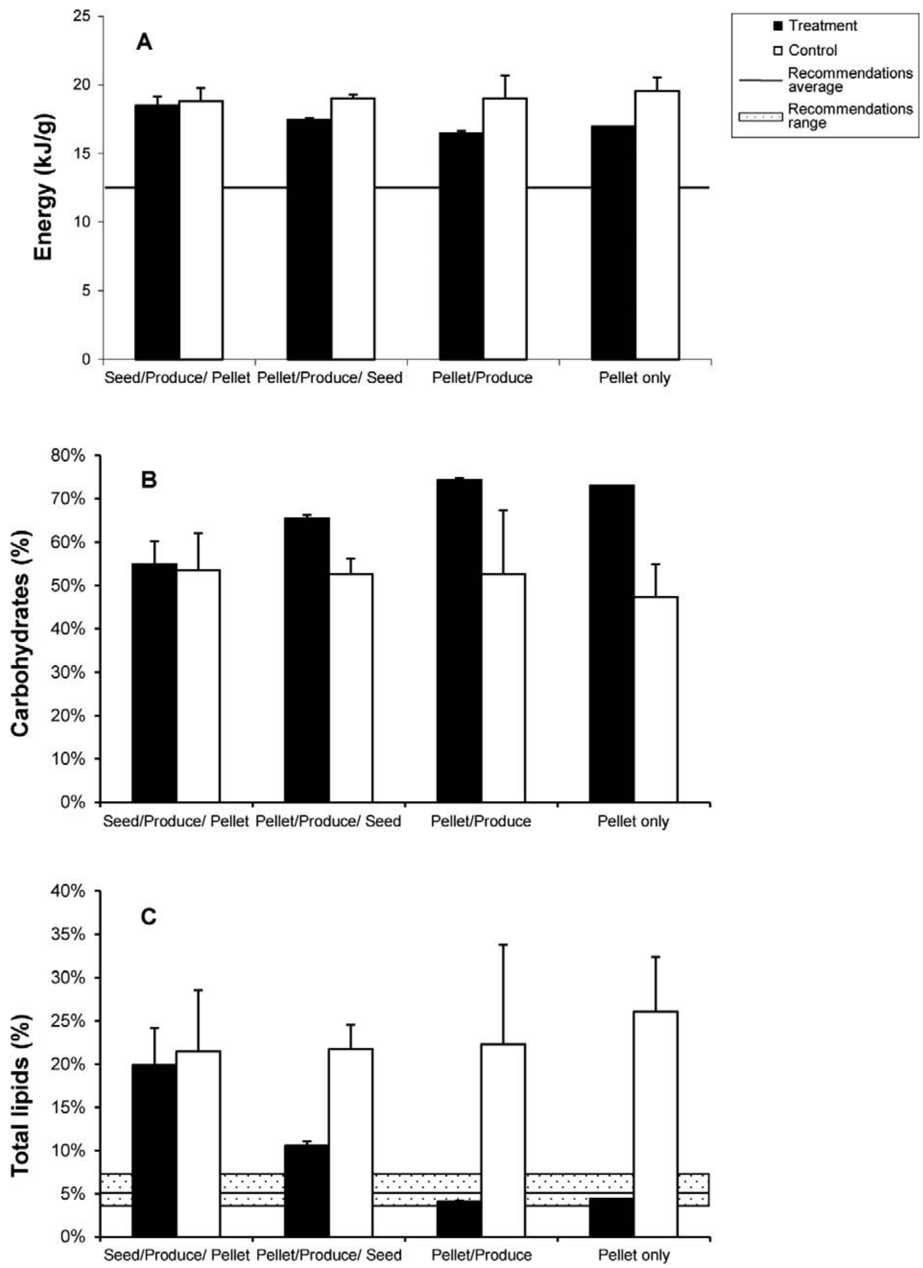

Figure 1. Energy (A), carbohydrate (B), and total lipid (C) levels by dry weight in diets consumed by 7 captive Amazon parrots compared with dietary recommendations in the literature. Treatment birds (N = 4) were fed the diets indicated on the x-axis, whereas control birds (N = 3) were fed the same seed/produce/pellet diet throughout the experiment. Error bars show ± 1 SD. The number of recommendations used to calculate the mean and range are presented in Table 5.

the pellet-only diet. As a result, the amount of vitamin A and β-carotene consumed showed the same general patterns: both were highest in the diets with produce and reduced seed content (Mood's median test, $P < .05$; Fig 3).

As the amount of seed in the diet was reduced, both the calcium level and calcium : phosphorus ratio increased significantly (Mood's median test, $P < .05$; Fig 3). Phosphorus levels showed relatively little variation among diets (Mood's median test, $P > .05$ for all pairs). The magnesium level was significantly higher in the seed/produce/pellet diet compared with the pellet/produce/seed, pellet/produce, and pellet-only diets (Mood's median test, $P < .05$). However, potassium levels showed little variation among the diets and were slightly greater than recommended values (diet range, 0.72% pellet-only to 0.79% pellet/produce/seed; recommended range,

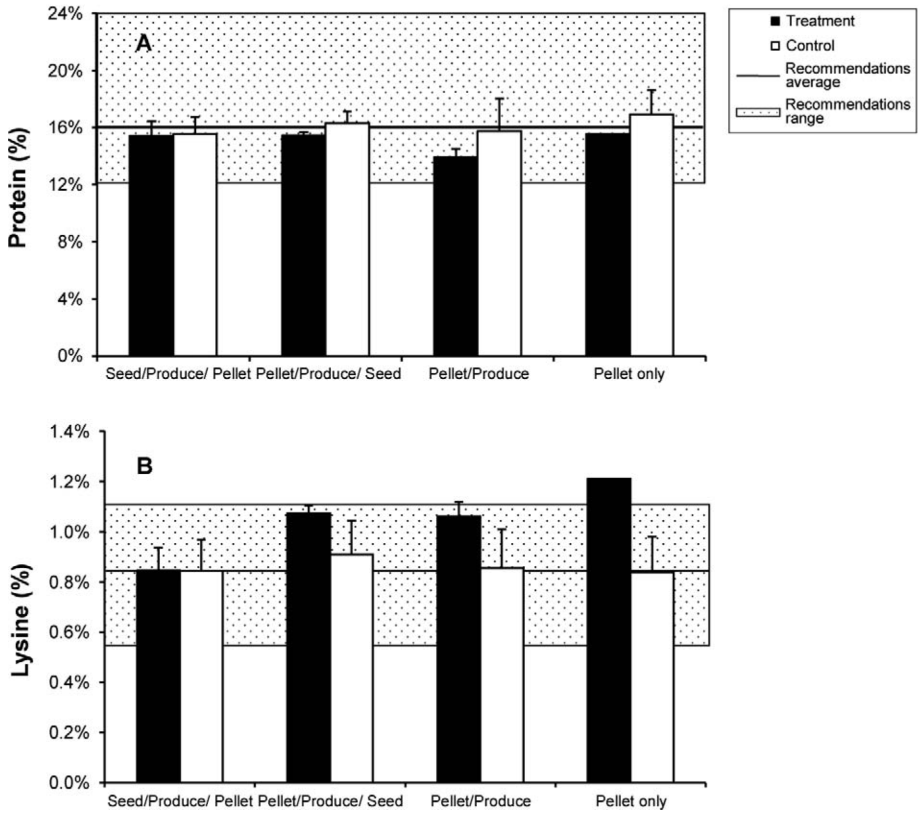

Figure 2. Protein (A) and lysine (B) levels by dry weight in diets consumed by 7 captive Amazon parrots compared with published dietary recommendations. Treatment birds (N = 4) were fed the diets indicated on the x-axis, whereas control birds (N = 3) were fed the same seed/produce/pellet diet throughout the experiment. Error bars show ± 1 SD. The number of recommendations used to calculate the mean and range are presented in Table 5.

0.40%–0.70%).[3,9,38] The sodium levels were significantly higher in the pellet/produce/seed, pellet/produce, and pellet-only diets compared with the original seed/produce/pellet diet (Mood's median test, $P < .05$; Fig 3); however, all were well below the 0.15%–0.2% recommended in the literature.[3,9,13,38] Iron levels were significantly higher in diets with reduced seed or no seed and were within the recommended range (Mood's median test, $P < .05$, Fig 3).[3,9,38] Copper values showed little variation among the diets and were all well within the recommended range.[3,9,38] Zinc values were significantly higher in birds fed pellet/produce/seed, pellet/produce, and pellet-only diets compared with the original seed/produce/pellet diet (Mood's median test, $P < .05$) but were well within the recommended range of 45–120 ppm for all diets.[3,9,38]

Discussion

The original diet of produce (~50% fresh weight), formulated diet (~25%), and seed (~25%) as fed contained high quantities of oil seeds and was nutritionally imbalanced. Seed-only diets are known to be deficient in a variety of nutrients, including calcium, phosphorus, lysine, sodium, zinc, iron, and vitamin A.[3,10,13] This study suggests that supplementing seed diets with produce and formulated diet improved the levels of lysine, phosphorus, zinc, and vitamin A. However, the mixed diet was still apparently deficient in calcium, sodium, and iron and had much more total lipid than recommended (Table 5). Ullrey et al[3] reported that seed diets supplemented with pellets and produce were still deficient in methionine, calcium, phosphorus, sodium, zinc, and vitamin A because birds did not consume sufficient quantities of formulated diet. Hess et al[4] found that pet parrots consuming <25% pellets, such as the ones in this study, suffered from an excess of fat and an apparent deficiency of protein, energy, vitamin A, calcium, and phosphorus. As evidenced in this and other studies, the nutritional imbalances of seed-containing diets are exacerbated by birds choosing seeds with the highest fat content.[10] The research to date shows incontrovertibly that seed-rich diets contain excessive levels of fat, a

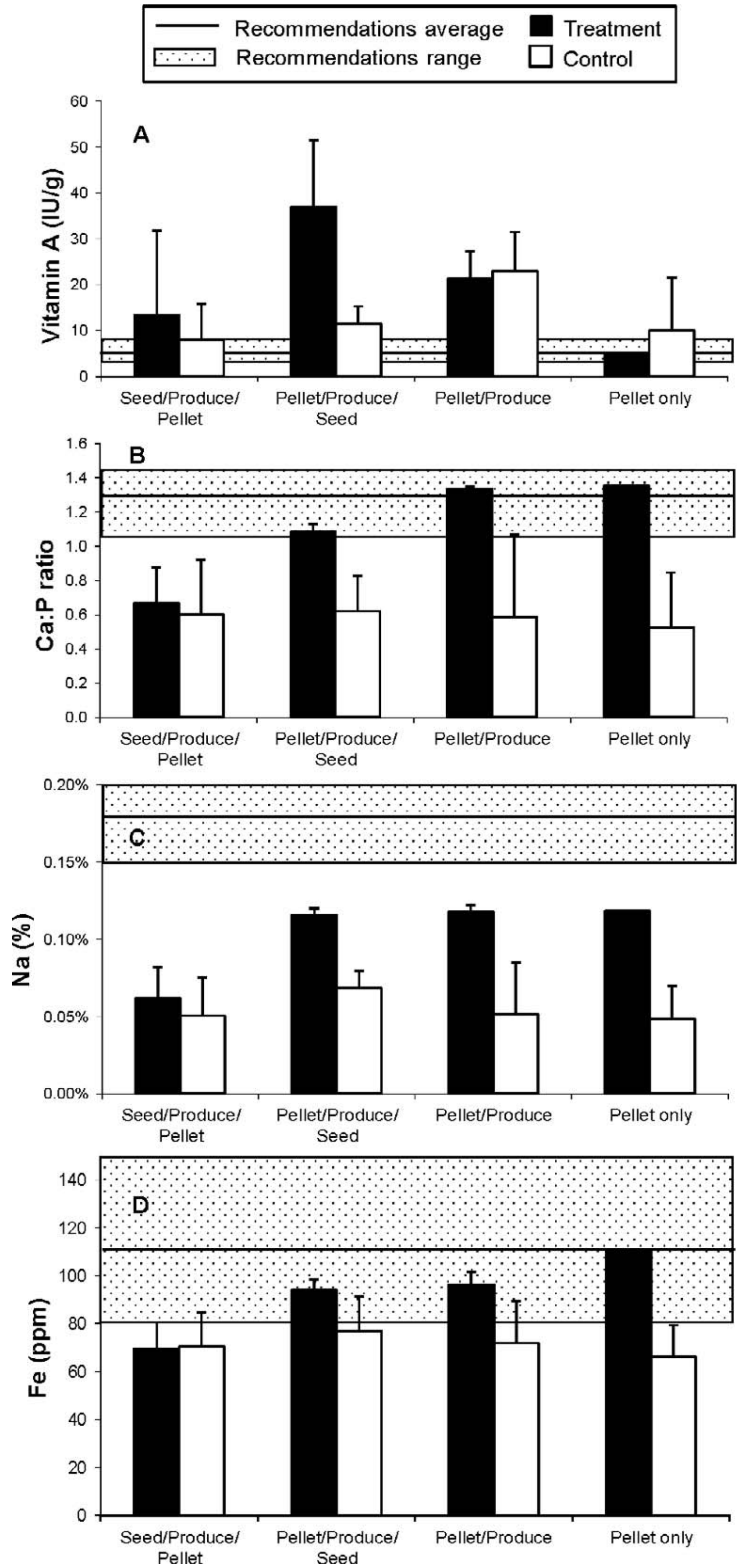

Figure 3. Vitamin A concentration (A), calcium : phosphorus ratio (B), sodium percentage (C), and iron concentration (D) by dry weight in diets consumed by captive Amazon parrots compared with published dietary recommendations. Treatment birds (N = 4) were fed the diets indicated on the x-axis, whereas control birds (N = 3) were fed the same seed/produce/pellet diet throughout the experiment. Error bars show + 1 SD. The number of recommendations used to calculate the mean and range are presented in Table 5.

deficiency of calcium, and poor calcium : phosphorus ratios.[10,23]

The birds in the study consumed ≤40% of the total food offered and ate ≥75% of the total quantity offered for a select few items including grapes and high-fat seeds. This suggests that the birds had the ability to choose a more nutritionally balanced diet through selective eating. However, as found in previous studies, selective consumption skewed their diets even further from recommendations.[3,5] For example, diets offered were higher in fat and total energy density than recommended, and the birds consumed diets even higher in both. Conversely, diets offered were lower in calcium, sodium, and calcium : phosphorus ratio than recommended, and the foods consumed were lower for all 3 nutrients.

Diet conversion experiment

By converting the birds from a seed/produce/pellet diet to a pellet-only diet, the nutritional imbalances of greatest magnitude were corrected (ie, fat was reduced, whereas calcium levels and the Ca : P ratios were increased), and no new imbalances were detected. Sodium levels remained lower in the diets offered than the recommended level of 0.15%–0.2%, but the recommendations are based predominantly on poultry studies, and there is no evidence that parrots require such high levels.[3,9,13,38] In fact, many wild parrots apparently survive on diets with sodium levels much lower than those recommended in the literature.[40,41]

The birds on the low-seed diet (60% pellet/22% produce/18% seed by wet weight) consumed more fat than the recommended 10% but consumed acceptable levels of calcium and all other measured nutrients as well as an acceptable Ca : P ratio. This suggests that a similar diet may be appropriate to promote weight gain and for birds with higher than normal caloric expenditures, including fully flighted birds, breeding birds, and birds kept in cold ambient temperatures.

Manufacturers of formulated diets vary in their recommendations for supplementing diets with produce. Suggested protocols include (with N = number of manufacturers): 1) offering produce as an optional treat (N = 3); 2) supplementing the diet with produce but suggesting no specific quantity (N = 1); 3) offering produce as <10% of the diet by weight (N = 1); or 4) providing produce as <20% by weight (N = 2).[15–22] The diet of the birds on the 75% pellet/25% produce diet was within the recommended dietary ranges for the same suite of nutrients as it was for the birds on the 100% formulated diet. This finding is similar to that found by Ullrey et al,[3] which showed that a diet consisting of as much as ∼60% produce fresh weight and 40% formulated diet was nutritionally balanced. These findings suggest that a mix of produce and formulated diet can meet the nutritional requirements of captive parrots and that the total wet weight of produce offered can be greater than the 0%–20% recommended by diet manufacturers.[3] Produce does not skew the nutritional balance of formulated diets because of its high water content and relatively low caloric density. As a result, diets of 25%–60% produce by wet weight can still contain >80% formulated diet by dry weight as long as the supplemented items have a relatively low energy density.[3] Because foraging is considered an important component of environmental enrichment for captive parrots,[14] owners should be encouraged to offer low energy-density fruits and vegetables.

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References

1. Harrison GJ, McDonald D. Nutritional considerations: section II. In: Harrison GJ, Lightfoot TL, eds. *Clinical Avian Medicine*. Palm Beach, FL: Spix; 2006:108–140.
2. Bavelaar FJ, Beynen AC. Atherosclerosis in parrots: a review. *Vet Q*. 2004;26(2):50–60.
3. Ullrey DE, Allen ME, Baer DJ. Formulated diets versus seed mixtures for psittacines. *J Nutr*. 1991;121(11 suppl):S193–S205.
4. Hess L, Mauldin G, Rosenthal K. Estimated nutrient content of diets commonly fed to pet birds. *Vet Rec*. 2002;150(13):399–404.
5. Carciofi AC, Duarte JMB, Mendes D, de Oliveira LD. Food selection and digestibility in yellow-headed conure (*Aratinga jandaya*) and golden-caped conure (*Aratinga auricapilla*) in captivity. *J Nutr*. 2006;136(7 suppl):2014S–2016S.
6. Harrison GJ. Twenty years of progress in pet bird nutrition. *J Am Vet Med Assoc*. 1998;212(8):1226–1230.
7. Earle KE, Clarke NR. The nutrition of the budgerigar *(Melopsittacus undulatus*). *J Nutr*. 1991;121(11 suppl):S186–S192.
8. Roudybush TE, Grau CR. Food and water interrelations and the protein requirement for growth of an altricial bird, the cockatiel (*Nymphicus hollandicus*). *J Nutr*. 1986;116(4):552–559.

9. Stanford M. Nutrition and nutritional disease. In: Harcourt-Brown N, Chitty J, eds. *BSAVA Manual of Psittacine Birds*. 2nd ed. Quedgeley, UK: British Small Animal Veterinary Association; 2005:136–154.
10. Kalmar ID, Veys AC, Geeroms B, et al. Effects of segregation and impact of specific feeding behaviour and additional fruit on voluntary nutrient and energy intake in yellow-shouldered Amazons (*Amazona barbadensis*) when fed a multi-component seed diet ad libitum. *J Anim Physiol Anim Nutr*. 2010;94(6):E383–E392.
11. KAYTEE Forti-Diet Pro Health Parrot. Kaytee Products Inc Web site. http://www.kaytee.com/products/kaytee-fortidiet-pro-health-parrot.php. Accessed March 22, 2012.
12. 8in1—bird diets: Ecotrition Essential Blend–for parrots. Spectrum Brands Inc Web site. http://www.eightinonepet.com/products.php?display=67&main=30. Accessed March 22, 2012.
13. Werquin GJ, De Cock KJ, Ghysels PG. Comparison of the nutrient analysis and caloric density of 30 commercial seed mixtures (in toto and dehulled) with 27 commercial diets for parrots. *J Anim Physiol Anim Nutr*. 2005;89(3–6):215–221.
14. Meehan CL, Millam JR, Mench JA. Foraging opportunity and increased physical complexity both prevent and reduce psychogenic feather picking by young Amazon parrots. *Appl Anim Behav Sci*. 2003;80(1):71–85.
15. Mazuri parrot maintenance diet. http://www.mazuri.com/product_pdfs/56A8-5EE5.pdf. Accessed March 22, 2012.
16. Home bird care guide. Rolf C. Hagen Inc Web site. http://www.hagen.com/pdf/birds/bird.pdf. Accessed March 22, 2012.
17. Common questions. Roudybush Web site. http://www.roudybush.com/index.cfm?fuseaction=birdbrain.commonquestions. Accessed March 22, 2012.
18. Premium daily diet pellets. LafeberCares.com Web site. http://www.lafebercares.com/pinnacle/premium-daily-diet-pellets/. Accessed June 5, 2012.
19. Lilac-crowned Amazon. Pretty Bird International Inc Web site. http://www.prettybird.com/birds/lilcrwnamaz.htm. Accessed March 22, 2012.
20. Using our foods. Harrison's Bird Foods Web site. http://harrisonsbirdfoods.com/ourfoods/supplements.html. Accessed March 25, 2012.
21. Products: pet birds. Kaytee Web site. http://www.kaytee.com/products/animal/pet-birds.php. Accessed March 25, 2012.
22. FruitBlend with natural fruit flavors: premium bird food. ZuPreem Nutritional Products Inc. http://www.zupreem.com/sites/zupreem.com/files/fruitblend2012datasheet.pdf. Accessed June 5, 2012.
23. Carciofi AC, Prada CS, Mori CS, Prada F. Evaluation of fruit-seed based diets for parrots (*Amazona* sp.), I: determination of food selection and nutritional composition. *ARS Veterinaria, Jaboticabal, SP*. 2003;19(1):13–20.
24. Welcome to the USDA National Nutrient Database for Standard Reference. US Department of Agriculture Web site. http://www.nal.usda.gov/fnic/foodcomp/search/. Accessed March 25, 2012.
25. AOAC International. AOAC official method 982.30. In: Horowitz W, ed. *Official Methods of Analysis of the Association of Official Analytical Chemists*. 18th ed. Gaithersburg, MD: AOAC International; 2011.
26. Llames CR, Fontaine J. Determination of amino acids in feeds: collaborative study. *J Assoc Off Anal Chem*. 1994;77(6):1362–1409.
27. AOAC International. AOAC official method 988.15. In: Horowitz W, ed. *Official Methods of Analysis of the Association of Official Analytical Chemists*. 18th ed. Gaithersburg, MD: AOAC International; 2011.
28. AOAC International. AOAC official method 994.12. In: Horowitz W, ed. *Official methods of analysis of the Association of Official Analytical Chemists*. 18th ed. Gaithersburg, MD: AOAC International; 2011.
29. AOAC International. AOAC official method 974.29. In: Horowitz W, ed. *Official methods of analysis of the Association of Official Analytical Chemists*. 18th ed. Gaithersburg, MD: AOAC International; 2011.
30. Quackenbush FW, Smallidge RL. Nonaqueous reverse phase liquid chromatographic system for separation and quantitation of provitamins A. *J Assoc Off Anal Chem*. 1986;69(5):767–772.
31. AOAC International. AOAC official method 971.30. In: Horowitz W, ed. *Official methods of analysis of the Association of Official Analytical Chemists*. 18th ed. Gaithersburg, MD: AOAC International; 2011.
32. Randall EL. Improved method for fat and oil analysis by a new method of extraction. *J Assoc Off Anal Chem Int*. 1974;57(5):1165–1168.
33. Subcommittee on Poultry Nutrition, National Research Council. *Nutrient Requirements of Poultry*. 9th ed. Washington, DC: National Academy Press; 1994.
34. Harper EJ. Estimating the energy needs of pet birds. *J Avian Med Surg*. 2000;14(2):95–102.
35. Miller DD, Rutzke MA. Atomic absorption and emission spectroscopy. In: Nielsen SS, ed. *Food Analysis*. 3rd ed. New York, NY: Kluwer; 2003:401–421.
36. Gibbons JD. *Nonparametric Methods for Quantitative Analysis*. 2nd ed. Columbus, OH: American Sciences; 1985.
37. Brue RN. Nutrition. In: Ritchie BW, Harrison GJ, Harrison LR, eds. *Avian Medicine: Principles and Application*. Lake Worth, FL: Wingers; 1994:63–95.
38. McDonald D. Nutritional considerations: section I. Nutrition and dietary supplementation. In: Harri-

son GJ, Lightfoot TL, eds. *Clinical Avian Medicine*. Vol I. Palm Beach, FL: Spix; 2006:86–107.

39. Roudybush TE. Nutrition. In: Altman RB, Clubb SL, Dorrestein GM, Quesenberry KE, eds. *Avian Medicine and Surgery*. Philadelphia, PA: WB Saunders; 1997:27–44.

40. Brightsmith DJ, Matsafuji D, McDonald D, Bailey CA. Nutritional content of the diets of free-living scarlet macaw chicks in southeastern Peru. *J Avian Med Surg*. 2010;24(1):9–23.

41. Cornejo J. *Insights on Psittacine Nutrition Through the Study of Free-Living Chicks* [PhD Dissertation]. College Station, TX: Texas A&M University; 2012.